Evaluation of European lighting programmes

Utilities finance energy efficiency

Evan Mills

The beginning of least-cost utility planning in Europe is marked by 42 recent programmes offering financial incentives to encourage the use of energy-efficient compact fluorescent lamps (CFLs). Programmes have been conducted in six countries and manufacturers, retailers, and governments played active roles. Most of the programmes targeted residential consumers, but eight were available to commercial or industrial customers. Incentives included various combinations of give-aways, direct installation, rebates, wholesale discounts, and schemes in which consumers can gradually pay for their lamps via the utility bill. During the programmes, almost six million eligible households acquired two million CFLs. The average societal cost of conserved electricity was ¢2.1/kWh, including ¢0.3/kWh for indirect administrative, promotional, and evaluation costs. These programmes were cost-effective compared to the price of electricity or to the cost of new electric power plants. Increased demand for CFLs has helped to lower post-programme retail lamp prices by 20% to 50% for all consumers. The programme experiences shed light on a number of challenges for planners and policymakers.

Keywords: Energy efficiency; European conservation programmes; Financial incentives

When Thomas Edison first invented the modern electric light bulb, and the power production and distribution system to keep it burning, he envisioned a large electricity industry that would sell various energy services (eg illumination) to its customers.[1] His immediate goal was to compete with fuel-based lighting by offering similar lighting services (lamps plus electricity) at a lower cost. He charged his customers for the number of lamps installed in their homes – a proxy for energy services – rather than the actual quantity of electricity those lamps consumed. With this type of cost-recovery system, utilities stood to increase their profits if, by introducing more energy-efficient lamps, they could produce less electricity per unit of lighting services delivered. However, over the following century, the electric utility industry gradually chose to focus on selling energy rather than energy services. As a result, the efficiency of electric lighting today falls far short of its potential. This article describes how a number of European utilities have begun to actively promote efficient lighting and by doing so are returning to the founding precepts of their industry.[2]

Today, lighting is an important electricity end-use, responsible for 9% to 18% of all electricity demand in International Energy Agency (IEA) countries.[3] The IEA identifies an overall 'commercially feasible' savings opportunity to reduce the electricity used for lighting by more than 50% on a national scale.[4] As new technologies become available, this potential will grow.

Compact fluorescent lamps (CFLs) represent one of the most impressive end-use efficiency technologies. Compared to common incandescent lamps, CFLs typically require 80% less electricity per unit of light output. The higher first cost of CFLs is paid back in energy savings in a time period of roughly two years. Furthermore, over its lifetime a single 13-watt CFL will avoid the emissions of about 400 kilograms (1 000 pounds) of CO_2 into the atmosphere, assuming the lamp conserves electricity otherwise produced in a coal-fired power plant.

Although they have been commercially available for nearly a decade, and despite their attractive

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economics, CFLs have been slow to penetrate the lighting market, expecially in the residential sector. High first costs and lack of information on the benefits discourage most consumers. Availability of the lamps is also limited. A number of governments, manufacturers, and electric utilities interested in promoting energy efficiency have therefore decided that financial incentive programmes must be used to overcome consumers' reluctance to utilize CFLs.

The inception of European utility programmes to promote energy-efficient lighting can be partly traced to an old and leaky town-gas system in Stockholm. In 1986, the local utility considered converting some gas end-uses (mostly cooking) to electricity. However, upgrading the electricity distribution network promised to be costly and the utility wondered if investing in electricity efficiency could offer a less-expensive alternative. As the oldest end-use, and a familiar symbol of electricity, lighting was considered a good place to start. The utility met with one of the large lamp manufacturers to explore the possibilities. Encouraged by the availability of CFLs, the utility (Stockholm Energi) launched Europe's first effort to use financial incentives to increase the use of these lamps in the residential sector. This also marked Sweden's first utility-initiated programme to increase electricity end-use efficiency in *any* sector *or* end-use.

Between late 1987 and mid-1990, 42 lighting efficiency programmes offering financial incentives had been conducted throughout Europe. Six of these programmes were available to residential and non-residential customers and two were available only to non-residential customers. Based on interviews with the programme managers and lighting industry officials, the following sections present information on programme impacts, cost-effectiveness and consumer response for the cases where adequate data are available (33 residential programmes).

Most of the utilities surveyed considered their lighting programmes as a first step towards the practicalities of becoming energy service companies. Related objectives were to cut peak demand and to help lower long-term retail lamp prices by boosting demand for the lamps. Most utilities also viewed their efforts to encourage increased efficiency as a way of addressing growing environmental concerns, especially with respect to the greenhouse effect.

USING FINANCIAL INCENTIVES TO PROMOTE CFLs IN EUROPE

To date, programmes promoting CFLs have been conducted in the European countries of Austria, Denmark, Italy, the Netherlands, Sweden, and West Germany.[5] Programmes have also been undertaken or are planned in Australia, Brazil, Canada, Chile, India, Mexico, and the USA. These programmes are generally smaller (measured by target group size and numbers of lamps and lamps/eligible household) than the European programmes. Most of the non-European programmes are pilot schemes whereas those described in this paper were almost all full-scale programmes available to all customers.[6]

The programmes were conducted and financed by various combinations of electric utilities, lamp manufacturers, lamp retailers, and governments. Utilities have devoted up to 1.9% of gross revenues to the CFL programmes. A broad range of approaches were used for promoting CFLs, and consumer incentives ranged from 10% to 100% of the lamp cost. The most common approach involved a rebate at the point of sale.

In some cases, lamps were simply given away to utility customers and/or employees. Give-away programmes were either conducted by mail or with door-to-door visits and direct installation in homes. The largest give-away programme delivered 240 000 CFLs to Danish households served by the SEAS utility.

The Danish utility NESA offered a 'pay-on-the-bill' approach combined with lamp rebates, enabling households and non-residential customers to make monthly installments rather than paying a relatively large sum all at once. In the Netherlands, households obtained their lamps at retail stores, but the payment was made over the course of a year via their utility bill. Utilities conducting give-away or rebate programmes demonstrated an ability to purchase large numbers of lamps at less than half of the retail price typically paid by households.

In several cases, lamp retailers co-financed and helped to operate programmes and manufacturers discounted wholesale prices at the same time as other incentives (eg rebates) were being offered. In Sweden's two largest cities (Stockholm and Gothenburg) manufacturers and utilities operated a residential rebate programme that included efficient lamps *and* fixtures that can accommodate them. Manufacturers have also played a role in diffusing the idea of lighting programmes among utilities and between countries.

Governments also supported some of the programmes. In the Netherlands, initiated by a push by the Ministry of Economic Affairs, a 1987 parliamentary motion on saving energy directed electric utilities to encourage the use of CFLs. The government later provided financial support for operating the first programme. In Denmark, the government eliminated a special luxury tax (of \$1.55/lamp) on fluorescent lamps and financed the evaluation of an early programme.

A non-residential German 'pay-on-the-bill' programme was unusual in several ways, including the fact that it was fully government-financed. The programme was available throughout the province of Schleswig–Holstein, of which Kiel is the capital, a region of Germany containing about 50 municipal utilities. The programme was targeted towards public institutions (schools, hospitals, government buildings, etc). An engineering firm that plans and constructs power plants organized the programme on behalf of the government, in cooperation with Philips and Osram, the lamp wholesalers, and the utilities. Beginning in mid-June 1989, lamps were offered to an eligible group of about 6 000 customers. Participants could pay for their lamps over a 7-year period (at 6% interest). During the programme, lamp prices were discounted by about 30%.[7] There were no limits on lamps per customer.

PROGRAMME IMPACTS

Information collected from the interviews and utility reports makes it possible to assess the penetration rates and cost-effectiveness of each residential programme. To maximize comparability of the programmes, the following definitions have been consistently applied in estimating their impacts. The term *eligible households* represents the number of households that could have participated in the programme, eg, those that received rebate checks. The number of *lamps received due to the programmes* generally reflects the number of rebate coupons redeemed, numbers of lamps given away, etc.[8] This leads to conservative estimates given that the existence of the programmes is known to have resulted in additional indirect lamp sales, ie the 'spill-over' effect.[9] The term *programme penetration* refers to the number of lamps received per eligible household as a result of the programmes.

The *cost of conserved energy* (CCE) is used here to measure programme cost-effectiveness. The *societal* CCE is calculated by dividing the annualized total programme cost by the annual electricity savings, and is measured in the same units as the electricity price or cost, ie ¢/kWh. The total programme cost includes all costs for the lamps, salaries, consultants, advertising, postage, evaluations, etc, (the 'total resource cost').[10] The societal CCE does not necessarily represent the individual perspectives of consumers or utilities, since programme costs are typically shared among several parties. Utilities and consumers also assign different time values to money and have their own concerns about budgets, cash flow, and profitability.

The impacts of each residential programme are shown in Table 1. The Table indicates programme type, whether or not the programme promoted a particular lamp size, any limits on how many lamps each participant could acquire under the programme, programme penetration, and cost-effectiveness.

Programme penetration and impacts on the lamp market

Residential programmes. The residential programmes have had a significant impact on national lamp sales, collectively resulting in the introduction of 2 million CFLs throughout Europe, for an average of 0.35 lamps/household over the 5.7 million eligible households. Penetration rates varied from 0.04 to 6.0 lamps/eligible household. Averaged over their *entire* national housing stocks, the Swedish programmes introduced 0.06 CFLs/household *v* 0.24 lamps/household in Denmark, and 0.23 lamps/household in the Netherlands. Interestingly, programme participation rates show no correlation with the incentive level (lamp price to the consumer after accounting for rebates, etc) (Figure 1). This result is the product of various factors, including effectiveness of promotion strategies, type of incentive, and restrictions in some cases on the number of lamps allowed to each participant.

Non-residential programmes. Six of the residential programmes were also available to commercial and/or industrial customers (see Table 1, note e). Purely non-residential programmes have also been held. Stockholm Energi's programme was perhaps the first in Europe, and offered information and education without financial incentives over a period of two years. No evaluation has been made of the impact of this programme. One regional body (Landsting) in the Stockholm area purchased about 50 000 CFLs for use in the public buildings it manages. In the first year of the on-going German Provincial programme in Schleswig–Holstein, 500 of the 6 000 eligible customers participated, buying 31 360 lamps (63 lamps/customer).

The Danish utility NESA has made the most careful evaluation of a non-residential programme.[11] In total, 1 135 of NESA's non-residential customers ordered an average of 13.2 CFLs/customer, with a range of 2.0 (agricultural) to 24.8 (public sector

Table 1. Programme descriptions and cost-effectiveness.

Country: Utility	Type of utility[a]	Programme description[b]	Eligible households	Lamps received due to programme	Penetration (lamps/household)	Eligible households (%)	Total cost to utility (US$1 000)	Cost paid by consumer[c] (US$/lamp)	Cost of conserved energy[d] Total utility (¢/kWh)	Indirect costs (¢/kWh)	Total society (¢/kWh)
Sweden											
Stockholm Energi AB			355 000	151 000	0.43		1 328	8	2.6	1.3	4.4
o/w programme 1 (1987)	G&D	Y-6-a, g	3 000	18 000	6.00	100	164	0	2.7	0.0	1.2
o/w programme 2 (1988)	G&D	N-1-c, h, k	355 000	70 000	0.20	10	623	8	2.6	1.5	4.6
o/w programme 3 (1989)	G&D	N-1-c, h, k	355 000	46 000	0.13	10	454	8	2.9	1.5	4.6
o/w programme 4 (1989)	G&D	N-U-h, k	355 000	17 000	0.05		88	16	1.5	1.5	4.6
Helsingborgs Energiverk (1988)	D	Y-1-a, g	53 000	35 000	0.66	66	282	0	2.4	0.2	0.9
Malmö Energi AB (1989)	D	Y-U-a, c, g, k	136 197	26 562	0.20	8	104	12	1.2	1.2	2.3
Kalmar Energi AB (1990)	D	Y-U-c, g, k	15 000	4 500	0.30		31	9	2.0	2.0	3.2
Sweden subtotal			559 197	217 062	0.39		1 746	7	2.4	1.1	3.5
Denmark											
EFFO			12 000	30 000	2.50		103	4	1.0	←	1.2
o/w programme 1 (1988)[e]	D&Coop	N-5-a, b, e, g	4 000	15 000	3.75	100	63	0	1.2	←	1.2
o/w programme 2 (1989)	D&Coop	N-4-d, h	12 000	10 000	0.83		34	7	1.0	1.0	1.1
o/w programme 3 (1990)	D&Coop	N-3-d, h	12 000	5 000	0.42		5	12	0.3	0.3	1.4
BHHH (1989)	D&Coop	N-U-h, j, m	23 492	12 000	0.51		6	20	0.2	0.2	2.5
ARKE A/S (1989)	D&Coop	Y-U-b, c, g, i	23 860	8 361	0.35		0	17	0.0	0.0	2.5
SEAS A/S (1989)	G&D&Coop	Y-2-a, f, g	120 000	240 000	2.00	98	2 222	0	2.7	0.4	1.2
KOH/KKF (1989)	D&Coop	Y-U-h, j, m	41 997	1 500	0.04		10	20	1.9	1.9	4.2
KØGE (1989)[e]	D	Y-2-a, g	5 990	11 980	2.00	100	111	0	2.7	–	1.2
ELFO, ELRO, & Randers (1990)	Coop	N-U-c, h, j, l	59 500	10 000	0.17		9	18	0.3	0.3	3.4
NESA A/S (1990)[e]	G&D	N-5-c, h, i, j	380 000	135 000	0.36	5	593	17	1.3	1.3	3.8
KBV (1990)[e]	D	Y-2-c, h, l	294 384	100 000	0.34		129	17	0.4	0.4	2.9
ELSAM [3 utilities] (1990)	G	Y-5-c, g	80 000	9 368	0.12	11	19	13	0.6	1.0	2.0
Denmark subtotal			1 057 223	558 209	0.53		3 203	9	1.7	0.6	2.2
Netherlands											
8 Provinces, 12 utilities[f]											
o/w programme 1 [Friesland] (1988)[e]	G&D	N-2-c, e, h, i, k	250 000	150 000	0.60		54	13	0.1	0.1	1.9
o/w programme 2 [EBA] (1989)	G&D	Y-2-c, h, i, k	375 000	200 000	0.53		64	10	0.1	←	1.1
o/w programme 3 [GEB] (1989)[e]	G&D	Y-2-c, h, i, k	191 500	75 000	0.39		52	10	0.2	0.2	1.4
o/w other programmes (1989)	G&D	Y-2-c, h, i, k	2 333 500	748 375	0.32		2 718	10	1.1	←	2.1
Netherlands subtotal			3 150 000	1 173 375	0.37	15	2 887	11	0.7	0.1	1.9
Germany											
Energi-Versorgungsunternehmen Schwaben	G&D	Y-2-c	104 200	61 000	0.08	8	252	6	1.9	0.3	1.9
Austria											
KELAG (Province of Carinthia)		N-2-c	180 000	10 000	0.06		27	12	0.8	0.3	2.0
Total or weighted average			5 050 620	2 019 646	0.35	14	8 116	10	1.2	0.3	2.1

Notes: [a] Type of utility: G = generating company; D = distributing company; and Coop = cooperative.
[b] A-B-C: A. programme restricted to a particular lamp wattage: (Y(es)) or (N(o)); B. maximum number of lamps: (U(nlimited)); C. programme delivery mechanism(s), according to the following key:
a. Give-aways (to employees and/or customers).
b. Direct installation.
c. Rebate coupon or other form of retail discount: cash.
d. Rebate coupon or other form of retail discount: 'buy-one, get-one-free' schemes.
e. Government subsidy to lamp buyers or utility.
f. Government removal of lamp luxury taxes.
g. Bulk lamp purchase (* = with savings split between utility and retailer).
h. Wholesaler lamp discounts to retail stores.
i. Pay-on-the-bill approach.
j. Retailer co-financing.
k. Manufacturer co-financing (other than lamp discounts), eg promotion.
l. 'Kits' available containing a variety of CFLs for testing in the home.
[c] Lamp prices paid by consumers are net of rebates or other discounts, but include sales taxes.
[d] The cost of conserved energy is the net annualized total cost (computed here with a 6% real discount rate) divided by annual electricity savings. The 'societal cost of conserved energy' includes programme costs (direct plus administrative costs), plus consumers' costs (less the value of avoided incandescent lamp purchases), plus any third-party financing (eg from government or retailers). Costs for programme administration are included in the 'Utility' CCE. Value added taxes on lamps are *not* included in the societal calculation (A 20%, D 14%, DK 22%, NL 18.5%, S 23.5%). Mid-1989 exchange rates are used throughout the article: 13.98 Austrian schillings/dollar; 7.735 Danish kronor/US dollar; 2.240 Dutch guilders/US dollar; 1.989 German deutschemarks/US dollar; and 6.700 Swedish kronor/US dollar.
[e] Also available to non-residential customers. Associated costs and lamp sales not included in the analysis, except for the Dutch programmes where it was not always possible to disaggregate the cost data by customer type.
[f] Provincial generating companies: Groningen, North Holland, Gelderland, Friesland, Limburg, Zeeland, Overijssel, and Utrecht. City generating companies: Groningen, Breda, Amsterdam (EBA), and Den Haag (GEB).

Assumptions for energy savings: Lamp operation time 4 hours/day, based on Swedish and Danish surveys. Annual electricity savings are 75 kWh/year/lamp (including 9% annual average transmission and distribution losses). Assumes that a 60-watt incandescent lamp (1 000-hour service life, $0.75 retail price) is replaced with a 13-watt compact fluorescent lamp (8 000-hour service life). Service lives shown are manufacturers' ratings for European conditions. Applying the assumptions normally used for North American conditions (10 000-hour CFL life and 750-hour incandescent lamp life) would lead to an average cost of conserved energy of ¢1.0/kWh.

buildings). Many industrial customers also had a high demand for the efficient lamps (eg 19.8/customer (chemicals), 8.0/customer (textiles), and 7.3/customer (paper and pulp, and steel)).

Overall Market Impacts. Figure 2 shows the rapidly growing sales of CFLs in several countries in which programmes have taken place. In the Netherlands, national sales quadrupled between 1987 and 1989 and are projected to rise 60% from 1989 levels in 1990. Annual sales in Denmark are projected to reach about 600/1 000 people in 1990. By contrast, sales in the USA reach only about 80/1 000 people.[12]

Monthly deliveries of CFLs to retailers in Sweden over a five-year time period are shown in Figure 3. Swedish sales have been growing despite the presence of the programmes, but during 1988 and 1989 one-third of *national* sales were attributable to the programmes, although they were only available to 15% of Swedish households. National pre- and

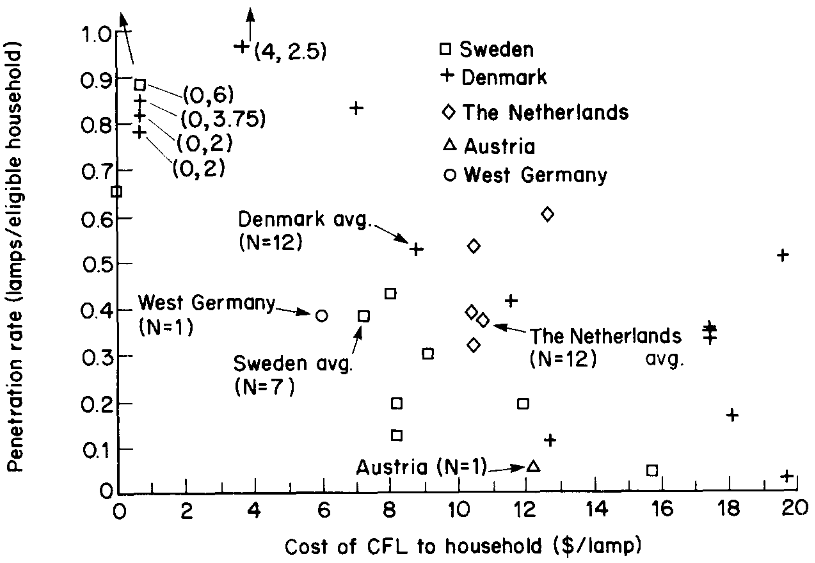

Figure 1. Programme penetration *v* incentive.

Note: Consumer incentive level and penetration rates (lamps/eligible household) are not well-correlated. See Table 1 for actual values. (N) refers to the number of programmes held in each country. Five data points are off-scale.

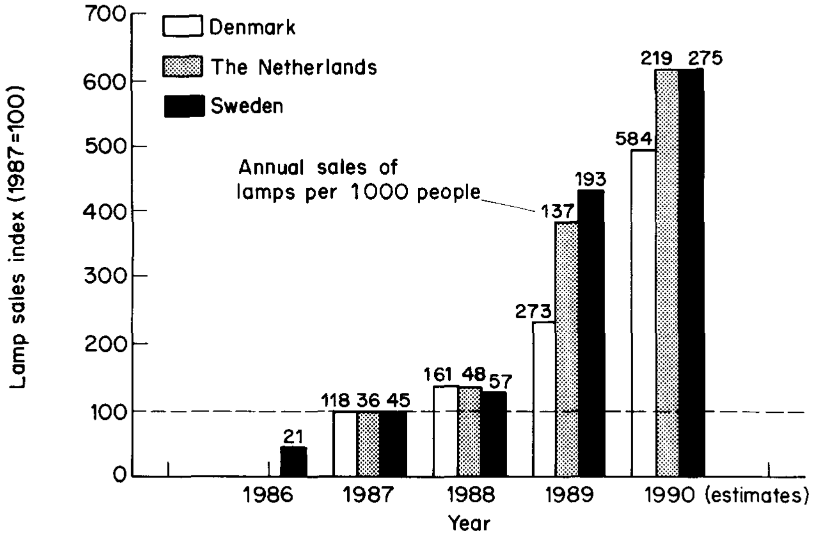

Figure 2. Increasing sales of CFLs during programme lifetimes.

Notes: Annual lamp sales statistics were provided by the lighting industry trade associations and individual manufacturers and include both PL-type (separable lamp and ballast) and SL-type (integral) lamps. Penetration is shown in terms of lamps/capita (rather than lamps/household) because the sales figures include residential, commercial, and industrial consumers. CLFs were introduced to the European market in the early 1980s.

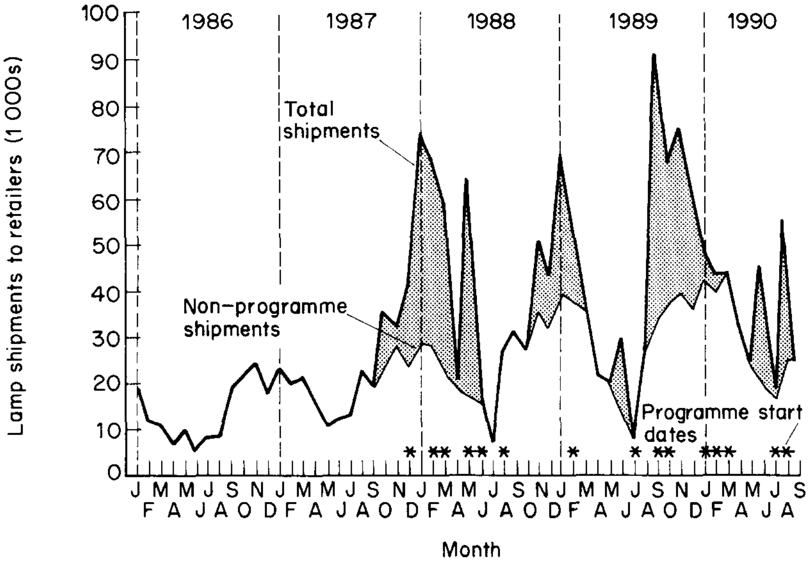

Figure 3. Impact of the lighting programmes on lamp sales: Sweden.

Notes: Values shown include shipments to retailers of integral (SL) compact fluorescent lamps ultimately purchased by residential and non-residential consumers. The 'non-programme' curve was estimated based on the non-programme sales data for Stockholm in each year as estimated by the Swedish lighting trade association (Ljuskultur). The beginning dates for the various incentive programmes are indicated below the monthly sales graph, and show how retailers add lamps to their inventories in anticipation of the programmes. The seasonality of sales reflects the greater burn-out rate of incandescent lamps in the winter months (shorter days) as well as the strategic timing of most of the programmes that have occurred. Note the Christmas-holiday dip in shipments each December.

Source: Derived by polling lamp distributors, personal communication, Magnus Frantzell, Ljuskultur, Stockholm.

post-programme sales data show that the Swedish, Danish, and Dutch programmes have been responsible for 80% to 95% of the lamps placed into service in the residential sector during the programme periods. This is consistent with shop owners' reports that CFL sales increase ten- to twentyfold during programmes.

CFLs are beginning to capture a significant share of the lighting market. In Sweden, for example, incandescent lamp sales in 1990 were approximately 70 million/year (70 billion lamp-hours). Given their eightfold longer service life, with currently 2 million lamps/year sold (16 billion lamp-hours) CFLs have effectively captured nearly 25% of the market.

Energy savings

In several cases, the utilities have surveyed lighting programme participants to determine usage of the efficient lamps in households. In each case, participants reported using the CFL to replace an incandescent lamp that was operated an average of about four hours/day. This corresponds to an annual savings of about 70 kWh/year in the case where a 13-watt CFL replaces a 60-watt incandescent lamp. Based on utility estimates of approximately 600 kWh/year total household electricity-use for lighting, households participating in the most effective programmes (four to six lamps/house) achieved at least 50% savings in electricity used for lighting.[13] This is possible because most electricity used for residential lighting is attributable to only a few of the 20 to 30 lamps commonly found in a home.

Assuming the aforementioned energy savings, the European programmes are collectively saving 150 GWh/year of electricity. For comparison, this is equivalent to the annual electricity used for appliances by 50 000 European households.

The number of applications for CFLs will increase as new lamps closer in size and weight to incandescent lamps are introduced. The availability of ballasts that can be placed away from the lamp (eg between the wall outlet and the plug) will enable the use of otherwise too-large CFLs in a greater number of sockets. Meanwhile, the availability of electronic-ballasted CFLs has increased the number of potential applications, since they are smaller, lighter, and their service lifetime is virtually unaffected by the frequency of on–off cycling.

Cost-effectiveness

From a societal economic perspective, all of the programmes are cost-effective in comparison to the prices paid for electricity by households and in comparison to the cost of building new electric power plants (Table 1). The average societal cost of conserved energy is ¢2.1/kWh, including indirect costs of ¢0.3/kWh. The best programme has a total societal cost of conserved energy of ¢0.9/kWh. These results are somewhat better than has been achieved in US programmes.[14] Programme cost-effectiveness does not correlate with the size of the eligible population or with the level of utility spending.

The payback time to participating households ranged from zero years (free lamps) to approximately three years. A longer-term benefit accrues to all consumers because, according to manufacturers, increasing demand for lamps due to the programmes has caused prevailing retail prices to fall. As an example, for Denmark, the suggested pre-programme retail price for the Osram 11-watt Dulux EL lamp was $32 until November 1989 at which time manufacturers decided to reduce the price to $20 nationally. By mid-1990, the national average price had fallen to $17.

The utilities have spent $8 million on the residential programmes, yielding an average cost of conserved energy of ¢1.2/kWh. This is less than the typical short-run marginal costs for fuel and plant operations. Utilities faced zero or negligible costs in cases where third parties (governments, lamp retailers, manufacturers) shared the programme costs. However, the programmes were not beneficial to utilities in cases where they led to insufficient capital recovery and hence lost revenues.

Although not analysed here, the non-residential programmes should be much more cost-effective than the residential programmes. This is partly because the need to contact fewer customers, plus the delivery of more lamps/customer, means lower administrative costs. Moreover, significant labour costs are saved because eight incandescent lamp replacements are avoided. Swedish utilities estimate the value of these labour savings to non-residential customers at about $25/CFL.

Cross-country comparisons

By many measures, the Danish and Dutch programmes were the most successful. The Dutch programmes were *available* to 61% of all households, the Danish were available to 43%, and the Swedish to 15%. Participation rates were modest and the average cost of conserved energy was highest in Sweden. This outcome is surprising, considering that Swedish consumers paid less for their lamps ($7/lamp on average) than did participants in Denmark ($9/lamp) or in the Netherlands ($11/lamp). Large lamp giveaways contributed to Denmark's relatively high overall programme penetration rate compared with the other countries.

The government stance towards the programmes differed markedly among countries. In Denmark and the Netherlands there was a clear desire on the part of the national governments for utilities to 'do something' about energy conservation. These governments gave both financial and moral support to the early programmes. According to the lamp manufacturers, the Danish government became much more interested in electric demand-side management in response to the UN's *Brundtland Report*, which called on governments to increase energy-efficiency to help combat global environmental problems.[15] In addition to essentially requiring utilities to begin CFL programmes in 1988, the Dutch government set a national goal of 3.5 CFLs/household by 1995. In contrast, the Swedish State Power Board (Vattenfall), Ministries, and other national agencies, were virtually inactive in using financial incentives to promote efficient electricity-use in Sweden during this period. With Vattenfall's new $150 million demand-side management programme, this situation should soon change.

Utility commitment has also varied among the countries. The largest power supply companies in Denmark and the Netherlands tended to be heavily involved in the programmes and, in the case of Denmark, later spread the results to their distributing companies. With the exception of Stockholm Energi, the major supply companies in Sweden were uninvolved with the programmes. The Danish programmes have employed the greatest variety of incentive mechanisms while, aside from employee-education efforts and the relatively small programme in Helsingborg, the Swedish and Dutch utilities have not chosen to utilize the most cost-effective approaches (lamp give-aways). Swedish utilities have devoted a smaller portion of revenues to the programmes than have Danish utilities. Only the Swedish utilities have not held financial-incentive programmes for commercial or industrial customers.

CONSUMER ACCEPTANCE

For several of the programmes, follow-up surveys were conducted to learn how the lamps were used and to assess consumer acceptance. Some of the findings are summarized below.

Based on a survey of 423 households participating in the Stockholm programme, the majority thought they obtained more light from their new CFL than from their old lamp.[16] About two-thirds of the respondents reported using the new lamps for the same or fewer numbers of hours than their old lamps.[17] About two-thirds of the participants were satisfied with the brightness and colour quality of the lamps, but less than half were satisfied with their appearance and many had trouble fitting the lamps into their existing fixtures.

The survey also identified customers' reasons for participating or not participating in the programme (Figure 4). Interestingly, in only about half the cases were lower energy costs cited as the primary reason for participating. Trying a new technology and using the rebate check were the other frequently cited reasons. Participants also valued the longer lifetime of the efficient lamps. Non-participants reported a number of reasons for not redeeming their rebate checks, including general lack of interest, excessive lamp prices, non-awareness of the programme, or because lamp size/weight was unacceptable. Three quarters of the non-participants recalled seeing the rebate check in their mail but only one-third recalled seeing the lamps in stores.

A post-programme survey of 500 Malmö households showed that only half were aware that the programme had occurred.[18] Of those who had heard of the programme 20% bought one or more lamps. Of the participants, 92% reported being very satisfied with their lamps. Saving energy was cited as a reason for participating in only 39% of the cases, while saving *money* was cited in only 8% of the cases! Among the reasons for non-participation: lamp price too high (24%), lack of interest (13%), no lamps left on three hours or more (10%), and difficulty fitting the lamp into existing fixtures (6%).

In an evaluation of the first programme in Denmark, 94% of the 1 700 households surveyed had a positive overall reaction.[19] Only 44% were certain that they would buy a replacement CFL in the future, while 7% did not expect to buy a replacement lamp. The programme evaluators concluded that future lamp prices are the key factor in determining eventual replacement rates among the currently undecided customer group.

An evaluation of the most recent Danish programme focused more on the issue of lamp prices than have other evaluations.[20] The approximately 2 000 responding participants identified excessively high lamp prices as the main pre-programme barrier to their purchase of CFLs. At 1990 retail prices of around $15 (which had been reduced by 50% in 1989), 81% of the participants said that they would buy more CFLs in the future. Assuming prices dropped to $10, 92% said they would buy more CFLs, whereas given a price in-

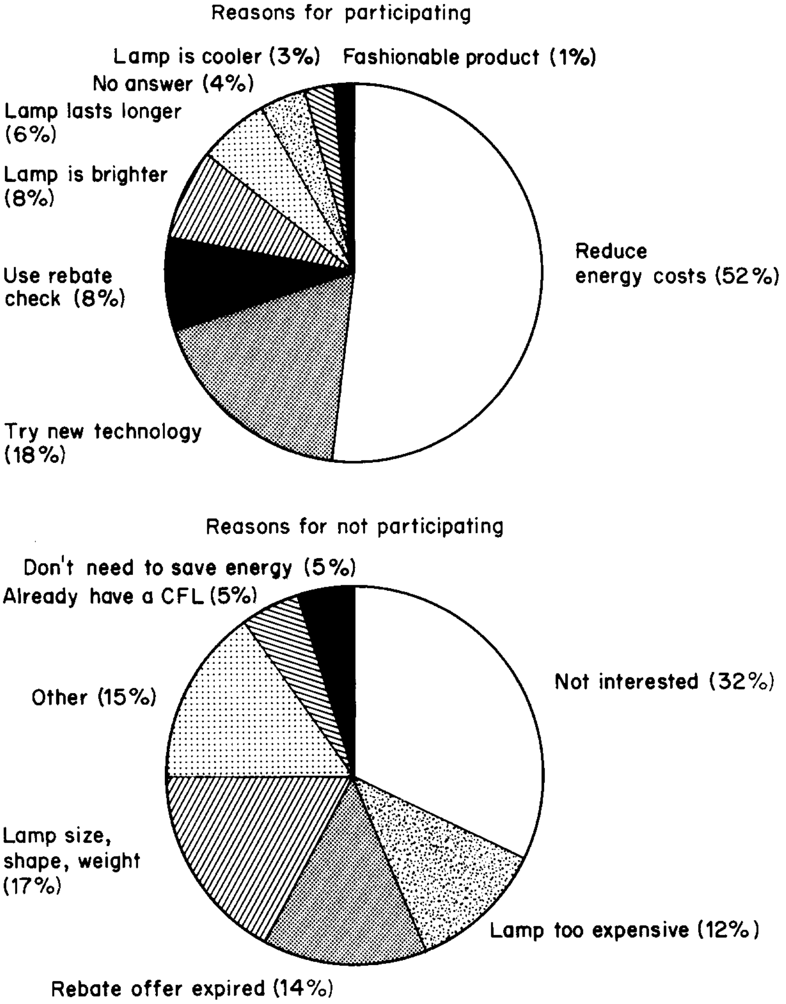

Figure 4. Household response to the Stockholm lighting programme (1989).

crease to $20 only 28% would buy more CFLs. The survey revealed other interesting factors. 'Convenience' (presumably long lamp life) was cited as the strongest advantage of CFLs over incandescent lamps. Environmental considerations were listed as motivations for buying CFLs in 50% of the cases and as the sole motivation in 10% of the cases.

In the Netherlands, Philips surveyed 4 000 households.[21] Responses varied considerably across the eight provinces in which programmes had been held. Between 8% and 20% of the households had participated, and between 45% and 75% of the households were aware of the programmes. Of the non-participants, up to 48% thought they had no need for CFLs, and up to 31% thought they were still too expensive. Half of the programme participants reported an intention to buy CFLs in the future.

LESSONS FOR PROGRAMME PLANNERS AND POLICYMAKERS

The programmes described in this article have captured only a fraction of the potential cost-effective national energy savings. Following is a discussion of lessons learned that could help in the planning of future programmes and in the identification of tasks facing policymakers.

Effect of utility involvement on total societal cost

An important policy issue is the impact that the cost of utility involvement in demand-side programmes has on the resulting overall societal cost of conserved energy. For the programmes decribed in this article, administrative and other 'transaction' costs contributed ¢0.3/kWh ($1/lamp) to the total cost of conserved energy. However, even when this cost is included, the programmes achieved substantially *lower* CCEs than would have been the case if consumers had bought the lamps on their own. This is due to the low prices that utilities can obtain when cooperating with lighting vendors or when buying lamps in large quantities.

Effect on the market and retail prices

The lighting programmes have opened up and accelerated the market for CFLs in the household sector, where before manufacturers saw little or no market. In Sweden, Denmark, and the Netherlands programmes have increased *national* residential lamp sales by four- to fivefold. Manufacturers in Denmark and the Netherlands note that the increased demand for lamps has led to approximately 50% and 20% lower post-programme retail prices for all consumers.

Type of incentive

The European programmes have employed a wide range of incentives. The lack of correlation between incentive levels (lamp price) and programme penetration rates suggests the importance of delivery mechanisms, effective promotion, etc. Give-away programmes resulted in the highest penetration rates (lamps/eligible household) and the lowest societal costs of conserved energy. When given a choice, consumers in Denmark and the Netherlands chose on-the-bill financing in at least two-thirds of the cases. Non-residential participants also preferred the on-the-bill option. This mix of preferences suggests that different consumer groups prefer different types of incentives. Interestingly, in the NESA programme 60% of the consumers choosing on-the-bill payments purchased their limit of five lamps, while only 20% of the cash-paying households bought five lamps.

The Swedish National Energy Administration, in cooperation with manufacturers and four utilities, is currently testing four types of incentives and conducting a detailed follow-up survey. The incentives are: (1) manufacturers offer a rebate to the consumer; (2) manufacturers and the utility share the cost of the rebate; (3) the rebate is apportioned two-thirds to the consumer and one-third to the retailer, and (4) a manufacturer-paid rebate is refunded to the customer via the utility bill.

Information v financial incentives

Exhibitions, open houses, and other 'low-effort' approaches have yielded minimal impacts compared to programmes offering financial incentives. Nonetheless, as evidenced by the large indirect lamp sales in some programmes, improving consumer information can help increase the effect of financial incentives.

Future programmes should address the problem that consumers often have inaccurate or inadequate information on CFLs. Most consumers (and many utilities) are unaware, for example, that CFLs are becoming lighter and smaller, their colour quality is approaching that of traditional incandescent lamps, or that CFLs with electronic ballasts have no perceptible flicker and can be cycled on and off at short intervals without shortening lamp life.

Labelling of lighting products is an obvious way to relay information to consumers. The Swedish lighting trade association has introduced a new logo to be used on labels for efficient lamps to help consumers identify the fixtures that will accommodate CFLs. Labels can also be used to help overcome misconceptions about lamp characteristics, as exemplified by Osram's prominent label (on their lamps with electronic ballasts) showing that there is no reduction of lamp life with frequent on–off cycling. Osram has also listed the net cost savings for CFLs on their packaging, with separate listings for 14 countries.

Programme design

New kinds of programmes could increase participation rates. Lamp-leasing programmes, for example, have not yet been tried in Europe. The first European catalogue-based programme is now planned in southern Sweden. In the USA one catalogue-using company has sold 200 000 CFLs in four years. Innovative procurement exercises (where large purchasers of lamps could request new products, eg luminaires with built-in electronic ballasts) have also not yet been tried in Europe although the Swedish National Energy Administration is now planning one such programme.

Programmes can be expanded to promote the lighting fixtures with built-in ballasts for CFLs. This is being done for the first time in Europe in a joint utility–manufacturer programme in which coupons for a total of about $100 rebates on CFLs and fixtures have been sent to each household served by Stockholm Energi, Gothenburg Energiverk, Halmstad Energiverk, Nyköping Energi, Stora Kraft, and Karlstads Energiverk.

As yet, no European utilities have bundled CFL programmes to promote other energy-efficient technologies. Offering packages of measures provides an efficient way to maximize consumer choices and to reduce programme costs.

Cooperation with trade allies

Lighting trade organizations and/or individual manufacturers have helped European utilities to organize and run some programmes. Manufacturers typically lowered wholesale prices to complement a financial incentive offered by the utility, although in some cases manufacturers initiated the programme and then enlisted the utility support. The benefits of cooperation flow in both directions. Swedish lamp manufacturers report that they would not have made an effort at marketing to residential consumers if it had not been for the surprising (to them) success of the Stockholm programme. In the USA, Taunton Municipal Light and Power's SMARTLIGHT lamp-leasing programme concept was purchased by Philips Lighting for use elsewhere. Cooperation with trade allies has been identified as an important element of success in utility-sponsored lighting programmes in the USA.[22]

Involving lamp retailers is also important. Retail display space is valuable and retailers are justifiably concerned that they will lose money if lamp sales are slow. This concern often leads retailers to shy away from CFLs or to offer only a very limited selection. Solutions could involve, for example, utilities guaranteeing to pay the rent on the display space required for a lamp campaign.

Harmonizing with the market

Carefully conceived programmes can build up long-term demand for efficient lamps and thereby benefit manufacturers and retailers. Problems are likely to arise if only certain products are included in programmes. This occurred in Germany, where Energie-Versorgungsunternehemen (EVU) Schwaben held a programme featuring only Osram lamps. A law suit was filed and the courts decided that campaigns must promote at least two different manufacturers' products.

Short-term adverse impacts on lamp wholesalers, distributers and retailers, and ensuing tensions between them and the electric utilities should be guarded against. The large discounts that are applied during some programmes reduce or eliminate profits. Price discounts can also lead to price eruptions at the close of a campaign, although this can be tempered when campaigns boost sales enough that profit margins are willingly relaxed. Give-away programmes are no doubt useful in 'seeding' the market, but in the long-term the needs of the various market actors must not be neglected.

Lamp availability as a key bottleneck

Availability of CFLs was often a limiting factor in the success of the programmes. Shop-owners sometimes underestimated the response to a forthcoming programme and did not build up their inventories. As a result, they sold out of lamps and could not re-order quickly enough to take advantage of the remainder of the programme. In a more dramatic example, SEAS's order for 240 000 lamps dried up the *entire* European market for one brand of lamp for at least six months. During this time period, a programme designer in Sweden had intended to use that product, but had to switch to another after learning that their order could not be filled.

Manufacturers note that there is today a *global* shortage of CLFs and that current lamp manufacturing capacity is insufficient to support impending programmes. To help ensure that in the future capacity is sufficient to meet demand, data should be compiled on planned programmes and relayed to manufacturers and retailers on a regular basis. Meanwhile, as long as the supply of lamps from European factories is constrained, Europe cannot be looked to as a reliable source for lamps in other parts of the world.

Time dynamics

A critical factor in assessing the value of demand-side programmes is their lead-times. An important finding is that lighting programmes in large cities as well as small towns can be brought 'on-line' very quickly. Several months to a year of planning are normally required in advance of a programme and actual durations ranged from five to 90 days.

Also relevant to the issue of 'time dynamics' of demand-side management, we have seen that the programmes accelerated the market for CFLs. Based on a linear extrapolation of the 'non-programme' levels trend shown in Figure 3, lamp sales during the first year of the Swedish programmes would not otherwise have been attained until seven years later.

Free-riders

There is much hand-wringing among analysts of US demand-side programmes about the free-rider effect (ie programme participants who would have bought lamps even without an incentive). However, this was not commonly viewed as a significant (or measurable) problem by the European programme managers. At the worst, only the additional administrative cost – found to be quite small for the European programmes – from providing lamps to free-riders represents a true cost to society. In any event, the many-fold increase in lamp sales during the programmes suggests that the free-rider effect could not have been very large.

Takeback effects

The available statistics do not allow a precise evaluation of takeback effects (ie increased use of the efficient lamp in comparison to the inefficient lamps they replace). Of the Swedish programme participants surveyed, one-third reported that they used their CFLs for more hours per day than their old incandescent lamps. In the SEAS programme (Denmark), 22% reported using their lamps longer. Unfortunately, in neither case were respondents asked *how much* longer they used these lamps. As a hypothetical illustration, if all CFLs in the programmes shown in Table 1 were operated for 50% longer than the incandescent lamps that they replaced, energy savings would decline by about 10% and the average CCE would increase from ¢2.1/kWh to ¢2.5/kWh.

Programme evaluation

Better programme evaluations will be possible in the future if more concerted efforts are made to collect key data before, during, and after programmes are run. These data include: lamp sales, detailed programme costs, number of hours/year that lamps are operated, numbers of lamps received under a programme but never actually used, and consumers' intention to eventually replace the lamps received under a programme. To facilitate future cross-utility and cross-country comparisons, utilities should adopt standardized programme evaluation protocols.

Concern about mercury in fluorescent lamps

Each CFL contains about 5.5 mg of mercury. Many observers are concerned about uncontrolled mercury releases that occur when fluorescent lamps are disposed of improperly. To address this problem Stockholm Energi encouraged the establishment of collection points (typically located at gas stations), and the cost of recycling the mercury ($0.75/lamp) is paid by the county. The Malmö Energi programme promotion materials noted that the local municipal garbage and sewer company would collect the bulbs. However, at present recycling services are not widely available and in at least one case waste disposal sites have discouraged utilities from promoting CFLs in Sweden.

It is important to consider that using efficient lamps can avoid the combustion of mercury-containing fuels used to make electricity. Including the mercury contained in the fuel used to generate the electricity, total life-cycle mercury releases (lamp + electricity) would be approximately 9 mg/CFL if coal is used. However, 20 mg of mercury emissions will be *avoided* compared to the case of using inefficient incandescent lamps.[23]

Mercury associated with lamps must also be put in perspective with other sources of mercury in society. If all homes in Sweden had five CFLs lasting 8 000 hours each, the annual national addition of mercury would be 20 kg, or only 0.1% of the total mercury contained in commercial products used in Sweden each year.[24] For comparison, of the 14 000 kilograms of mercury from all human sources in Sweden each year, 6 000 kilograms is contained in batteries and 1 400 kilograms in thermometers. Regardless of the small quantities of mercury in CFLs, recycling should be encouraged. A deposit–refund system, linked to the lamp price, might prove effective.

Lack of financial incentives for utilities

The level of genuine commitment to increased energy efficiency is perhaps the most important factor in the success of programmes to promote efficient lighting and other energy-saving technologies and practices. Under today's system for determining profits, energy-efficiency programmes are not necessarily profitable to private utilities even though they might be quite profitable for society. As is now occurring in the USA, new policies must be implemented to remove any financing rules that make utilities prefer supply investments to investments in increased end-use efficiency that are less costly to society.[25] Public utilities and distributing companies should, in principal, invest in efficiency measures that cost less than new power plants. However, the slowness with which public utilities in Europe are initiating activities to promote energy efficiency suggests that here too exists a need for incentives.

Greater success can be achieved in future programmes by addressing the barriers and policy challenges that these programmes have revealed. However, even the best programmes will capture only a fraction of the possible opportunities to increase the energy-efficiency of lighting. Policymakers must consider mandatory efficiency standards if they wish to further narrow the gap between the potential and achieved energy savings.

CONCLUSION

European electric utilities have successfully implemented large, cost-effective lighting programmes in a short time period. The lighting programmes have opened up and accelerated the market for energy-efficient compact fluorescent lamps. Such programmes have also significantly reduced retail lamp prices by stimulating increased demand for energy-efficient lamps.

The programmes described represent a very encouraging start to utility-supported financial incentives for energy-efficient lighting in Europe. In the future, other lighting end-uses must be addressed and incentive programmes should be targeted towards other end-uses and sectors.

Utilities, manufacturers, wholesalers, retailers, and governments have shown that they can cooperate to play important roles in programme success. However, where presently there is a greater economic benefit for utilities to sell energy instead of energy services – eg electricity instead of illumination – policymakers must consider strategies to make end-use efficiency investments at least as profitable as supply investments.

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[1]For an historical review of Edison's ideas about lighting see T.B. Hughes, 'Edison and electric light', in D. MacKenzie and J. Wajcman, eds, *The Social Shaping of Technology*, Open University Press, Milton Keynes, UK, 1985, p 39–52.
[2]Parts of this article are excerpted from E. Mills, A. Persson and J. Strahl, 'The inception and proliferation of European residential lighting efficiency programs', *Proceedings of the ACEEE 1990 Summer Study on Energy Efficiency in Buildings*, American Council for an Energy-Efficient Economy, Washington, DC, USA. Previous data are updated, a new country (Austria) has been included, and material on non-residential programmes has been added.
[3]International Energy Agency, *Electricity End-Use Efficiency*, Paris, 1989, p 70.
[4]*Ibid*, p 73. Potential cost-effective savings for the USA are estimated to be as high as 79%, excluding associated heating/cooling interactions. See A.B. Lovins and R. Sardinsky, *State of the Art: Lighting*, Rocky Mountain Institute, Snowmass, CO, USA, 1988.
[5]For more detail on the Swedish, Danish, Dutch, and German programmes, see Mills *et al*, *op cit*, Ref 2. Data are not yet available for the recent rebate programme in Italy or for six recent rebate programmes in Sweden.
[6]This article focuses on programmes combining financial incentives with aggressive promotion to large target groups. In Sweden and Denmark, there have also been a number of relatively low-effort attempts (open houses and exhibitions) to promote CFLs. Some utilities have held open houses at which they sold CFLs at 50% to 75% below ordinary retail prices. In at least one case, local stores simultaneously lowered lamp prices by about $8. These strategies have resulted in lamp sales in the hundreds *v* thousands or hundreds of thousands for the high-effort programmes described in the text.
[7]Prices, excluding VAT, were discounted to eg $14 (28 DM) for an Osram 7-watt lamp with an electronic ballast, *v* $21 (41.5 DM) before the programme.
[8]Presumably there are also cases in which lamps obtained under a programme were ultimately not installed in the home. Limited evidence suggests that this is not a significant problem. A survey in Malmö (completed just 14 days after the close of their programme) showed that 84% of the participants had already installed their lamp(s) and 6% were saving the lamp(s) to give as a gift. Lamps acquired under purely voluntary programmes, as opposed to unsolicited give-aways, are presumably used in most cases. This is confirmed in the case of the SEAS (Denmark) lamp give-away, where 8% of the lamps were not installed.
[9]Indirect lamp sales because of programmes can be significant, but have only been estimated in some cases. For example, the Swedish lamp manufacturers trade organization estimates that the 75 000 rebate checks redeemed in the Stockholm Energi programme 'leveraged' 41 000 additional lamp sales. According to the Dutch utilities, the GEB programme resulted in 25 000 direct sales *v* 50 000 indirect sales. The corresponding numbers for the Freisland utility were 60 000 and 40 000 CFLs.
[10]For a discussion of the total resource cost, see F. Krause and J. Eto, *Least Cost Utility Planning: A Handbook for Utility Commissioners. Volume Two: The Demand-Side*, prepared for the National Association of Regulatory Utility Commissioners (NARUC), Washington, DC, USA, 1989.
[11]P. Erichsen, *Statistisk Bearbejdning af Salget af Sparepærer i NESA's Kampagne* (Processing the Statistics on Sales of Energy-Efficient Lamps in NESA's Campaign), Report UD 1990–33, NESA, Hellerup, Denmark.
[12]Personal communication, M. Siminovich, Lawrence Berkeley Laboratory, Lighting Research Group, Berkeley, CA, USA.
[13]Values for Sweden from Gunnar Larsson, Swedish State Power Board, Marketing and Forecasting group. Values for Denmark from J. Møller, *Elbesparelser i Bøligsektoren* (Electricity Conservation in the Household Sector), Danish Association of Electric Utilities Research Unit, DEFU Technical Report No 258, Lyngby, Denmark, 1987 (in Danish).
[14]F. Krause, E. Vine and S. Gandhi, *Program Experience and Its Regulatory Implications: A Case Study of Utility Lighting Efficiency Programs*, Lawrence Berkeley Laboratory Report No 28268, Berkeley, CA, USA, 1989. The average CCE drops to ¢1.0/kWh if the results from Table 1 are re-calculated using the lamp lifetimes typically assumed in the USA (10 000 hours/CFL and 750 hours/incandescent lamp).
[15]The World Commission on Environment and Development, *Our Common Future*, Oxford University Press, New York, 1987.
[16]See Stockholm Energi, *Rabatten på watten* (Rebate on the watt), Stockholm Energi, Stockholm, Sweden, 1988; and Stockholm Energi, *Lönsam Upplysning* (Profitable Information), Stockholm Energi, Stockholm, Sweden, 1989 (both in Swedish).
[17]It is not surprising that some households burned their lamps longer, given that product literature urges that the old-style lamps with mechanical ballasts should not be operated for less than three hours at a time.
[18]P. Nilsson, *Uppföljning Kampanjen för Lågenergilampor Malmö Energi* (Follow up on the Campaign for Low-Energy Lamps: Malmö Energi), prepared for Malmö Energi, Malmö, Sweden, 1990 (in Swedish).
[19]B. Nielsen, K.H. Thomsen and J. Møller, *EFFO Forsøg med Lysstoflamper* (EFFO Project with Compact Fluorescent Lamps), Danish Association of Electric Utilities Research Unit, Technical Report No 276, Lyngby, Denmark, 1989 (in Danish).
[20]ELSAM, *Rapport før Pilotforsøg før Låvenergilamper* (Report on the Pilot Project for Low-Energy Lamps), Report N90/SP-220, ELSAM, Odense, Denmark, 1990 (in Danish).
[21]Personal communication, P. Hoeppener, Philips Lighting, Eindhoven (the Netherlands).
[22]See Krause, *et al*, *op cit*, Ref 14.
[23]Assumes a representative value of 4 micrograms of mercury per megajoule of coal-fuel and a 35% conversion efficiency at the power plant. Lamp characteristics assumed as described in the notes to Table 1.
[24]Swedish Environmental Protection Agency, *Kvicksilver: Problem, Miljömål, Åtgarder* (Mercury: Problems, Environmental Goals, Strategies), Naturvårdsverket Report No 3760, 1990.
[25]New policies to give California's electric utilities a return on their efficiency investments are described in *CPUC, Major Utilities Promote Energy Efficiency and Conservation Programs*, Press Release, California Public Utilities Commission, San Francisco, CA, 29 August 1990, USA. Similar policies have been implemented in New England.